Advanced Technological Solutions for E-Health and Dementia Patient Monitoring

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Chapter 3
Intelligently Adaptive Mobile Interfaces for Older People

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ABSTRACT

Computer technology has been reported to pose significant usability problems for older users. Further usability problems have been encountered with small, mobile computing devices due to their size as well as age-related declines. This chapter focuses on the usability of mobile computing devices for older people by first employing target users in a study to establish the problems to be addressed when using Personal Digital Assistants (PDAs). The development of an intelligent mobile interface companion called MemorLane to support older people by adapting its presentation and multimodal output of life-cached data to address individual user preferences and physical abilities is then presented, followed by the results of a detailed user-centred evaluation with further target users. Results show that the adaptability to individual requirements and preferences leads to statistically significant improvements both in the usability of the mobile interface and in the levels of user satisfaction experienced.

INTRODUCTION

As people live longer and the world's older population continues to increase rapidly new challenges have been posed to governments and society as a whole. How to cope financially is of major concern, and recent changes in retirement ages and pensions are evidence of pressures being faced. Of equal concern, however, is ensuring that older people can maintain quality lives, and remain independent for as long as possible. This is particularly challenging given the diversity of the older population in terms of their physical and cognitive requirements. The speed at which the world's older population is increasing is set to continue for the foreseeable future. By 2034, the

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UK's older population will have increased from 16% to 23% (Older People's Day, 2011). This sustained increase in the numbers of older people is evidenced throughout the world and places ever-increasing economic, social and health-care pressures on existing services.

In parallel with the growth in the older population is the increase in the use of computing technology in all aspects of everyday life. Many older people, however, are not adopting or fully utilising such technologies (Selwyn, 2004). Age UK (the amalgamation of Age Concern and Help the Aged) for example, reports that, in the UK in 2009, 60% of people aged 65 and over had never used the Internet; this equates to approximately 6 million people. Multiple reasons for this under-utilisation have been discovered. Often, it is simply a matter of choice, where older people actively choose not to use the technology because they don't want to. Selwyn (2004) suggests the reason for many older adults' ambivalence toward technology is that they perceive it as having little relevance to their daily lives. Another common reason relates to those who have tried to use it, but, having encountered many usability problems, either fear it or abandon its use altogether (Eisma et al., 2003; Fisk et al., 2004; Goodman et al., 2004; Zajicek, 2001). Computer technologies have been developed with the specific aim of assisting older people in their own homes often by supporting them with the tasks of daily life as the natural physical and cognitive declines of age take their toll. It has also been established that older people tend to be more willing to make use of computing devices and applications if they see a purpose for them (Selwyn, 2004).

This chapter presents the results of two studies conducted with older people. The first study established the usability issues associated with their use of a PDA. The results led to the design and implementation of an intelligent interface to adapt to meet each individuals' physical abilities and interface preferences. The second study evaluated the usability of the interface itself using an application identified in the first study as one of popular interest – reminiscence. The work presented in this chapter follows the User Sensitive Inclusive Design (USID) software development methodology (Newell and Gregor, 2000) which ensures that older end-users are involved throughout the development process. USID comprises five stages: requirements analysis; system design; implementation; system testing and evaluation. These stages are described in the following sections.

BACKGROUND

Research has been conducted into how to assist and encourage older people to make use of available computer technology by making the technology itself more user-friendly and intuitive for this age group. In particular, much work has focused on encouragement to use the Internet and email due to the benefits inherent in information access and communication. For example, the European DIADEM project (Delivering Inclusive Access to Disabled and Elderly Members of the community) involved researchers from the UK, Italy and Norway working together to assist older adults with online form access, completion and submission (Money et al., 2008). Hawthorn (2003) developed the SeniorMail application, an email system for novice, older users which includes a simplified interface. Many initiatives and organisations have been established to bridge the gap between older people and technology. Race Online 2012 is an example of a UK initiative which is aimed at making the UK the first nation in the world where every person can use the Internet. Race Online 2012 is supported by numerous partnerships (1041 partners to date) with government, industry, charities and individuals who have committed to help 1,910,703 people learn to use the Internet (Race Online 2012, 2011). One of the partners is Digital Unite (Digital Unite, 2011), a UK initiative which provides continuous support and training for older people to use computer technologies, with a network of specially trained tutors providing resources and training sessions throughout the UK.

In recent years, as small mobile devices such as ipods, mobile phones, smart phones, iphones, ipads and personal digital assistants (PDAs) have become more prevalent, their use by older adults has also become the focus of much research, and the benefits have again been recognised, particularly in the area of healthcare (Garritty and El Emam, 2006; Gillingham et al., 2002; Liang et al., 2003). Many further usability problems, however, have been identified for older users of such devices, mainly due to their small size but also to the natural physical declines which occur as part of the natural ageing process. For example, older people can find it more difficult to see the screen and to press keys. Problems also relate to the complexity of interaction required to use the mobile device. Research has been conducted to address these problems to some extent. For example, Sterns (2005) developed a PDA-based medication-reminder application for older adult users, with a custom-built interface which set off an alarm when medication was due, and a custom-built 'pill-box' was attached to the PDA to store the user's daily medication. Darroch et al. (2005) conducted a study which investigated the effect of age on participants' preference for font sizes on a PDA. Reading speed and accuracy were examined and results show that older users preferred font sizes between 8 and 12 and minimal text on screen.

REQUIREMENTS ANALYSIS

The involvement of older participants was central to the requirements analysis stage which determined the user requirements for the development of the mobile adaptive interface. A study was conducted with target users to establish the problems that older users encounter when interacting with a PDA. Fifteen participants (six males and nine females) took part in this study (n = 15). Participants were volunteers from the University of the 3rd Age (U3A), Age UK and local community groups. Participants' ages ranged from 55 to 82, with the mean age being 74. There were five age brackets where three participants were aged between 66-70, four aged between 71-75, four aged between 76-80 and three between 81-85. One participant fell into the unexpected 55-60 age bracket. This participant was a volunteer from the U3A, and while considered young for the study, was keen to participate with her older friend. Of the fifteen participants, seven had previous computers and mobile phone experience, one participant had mobile phone experience only, and seven had no experience with either computers or mobile phones. None of the fifteen participants had any previous experience of using a PDA. Experiments were conducted in one-to-one sessions where participants were given a demonstration of PDA interaction and functionality. Participants were shown how to interact using the PDA's 'physical' 5-way navigational button, 'touch-screen' using the PDA's own stylus, and 'touch-screen' using a finger. The help facility, and how to navigate the PDA's interface to access files and applications were also demonstrated. After the demonstration, participants were asked to complete five user tasks detailed in the following section. Sessions concluded with a post-experiment questionnaire and all sessions were observed with assistance given if required or requested.

User Tasks

Tasks were designed to test input and output modalities on a PDA in addition to ascertaining its general usability. The tasks required participants to use the three PDA interaction methods and interface components demonstrated such as the Start drop down menu, the File Explorer facility, and scroll bars. Tasks required use of four of its applications: Pictures & Videos, Windows

Media Player, Word Mobile and Notes, and were conducted consecutively. Participants were not restricted in the time allowed to complete each task and were instructed to attempt to use the PDA's help facility for any assistance required.

Task 1: Designed to ascertain the preferred method of interaction. Participants were asked to navigate freely through the interface using each of the three interaction methods in turn: the navigational button, stylus, and finger.

Task 2: Designed to ascertain the preferred text font size. As before, participants were asked to navigate to find a specific text file. The text file in question displayed five lines of text in font sizes eight to sixteen.

Task 3: Designed to find out how well participants could see and hear media files. As with Task 2, participants were required to navigate to locate three media files. Participants were asked to view each file: a photograph, a music clip and a video clip. The PDA's 'Pictures & Videos' application was used to display the photo file and the PDA's 'Windows Media Player' application was used to play the music and video files.

Task 4: Centred on the use of text input. The PDA's 'Word Mobile' application was used for this task. Participants were asked to enter their names via the on-screen keyboard.

Task 5: Centred on the use of audio input. The recording toolbar of the PDA's 'Notes' application was used for this task. Participants were required to record and replay a voice message.

Questionnaire Results

The post-experiment questionnaire comprised of eleven questions designed to establish task completion levels and general opinions on usability. Results show that all participants reported the PDA interface difficult to use, and there were twelve main problems identified:

1. On-screen text and objects were often considered too small to see and touch.
2. Remembering how to adjust default settings for on-screen objects was identified as a problem.
3. Difficulty was experienced in the use of the navigational button and stylus.
4. Finger interaction with the touch-screen proved problematic due to the small size of text and objects ((1) above), which forced the use of the navigational button or stylus which resulted in the problems reported ((3) above).
5. Participants found it difficult to hear the default setting for audio and found the functionality for changing the setting too complex. This was evidenced by comments such as, "I can't remember what you (the demonstrator) showed me".
6. Problems were encountered in seeing and selecting the correct screen objects. Participants reported too much clutter on the interface, in terms of, "There's too much stuff on the screen".
7. Difficulty was experienced in seeing and using the scroll bars.
8. Complex menu hierarchies which required many screen clicks for many tasks proved very problematic for participants. They commented that they, "Had to click too much", and many of these clicks were mistakes.
9. Navigating backwards and forwards between actions and use of the PDA's File Explorer facility was often problematic. Participants frequently, "got lost", and, "couldn't find the way back".
10. Participants also experienced difficulty in finding particular files, often commenting, "I can't find what I want".
11. The interface was not found to be intuitive. Participants often reported that they, "did not know what to do next".
12. Remembering how to find and use the PDA's help facility was also identified as a problem.

In general, participants found the PDA extremely complicated to use and had difficulty completing the tasks. This was evidenced by the level of assistance requested and given. From observation, no one found the interface instinctive or intuitive. Interaction proved time-consuming and often frustrating, with comments such as: "It's too difficult for me", "I don't remember where to click next", and, "I'm too old to learn this stuff!". During the one-to-one sessions it became apparent that many problems encountered were due to the varying physical abilities of this user group, notably eyesight, hearing and dexterity. Many participants referred to not being able to clearly see the items on screen due to their size and others found difficulty in selecting on-screen objects accurately as they were simply too small and close together.

During the one-to-one sessions, many questions were asked on a PDA's purpose, and some of its other applications were discussed, e.g. the Calendar. There was a noticeable level of general disinterest in many of the applications currently on the PDA. For example, most thought that its function as a calendar was of little interest as they preferred a pen and diary. Participants were however interested in its ability to store and present photos and music. When asked, many agreed that they would certainly be more interested, and inclined to engage with a PDA, if it provided an application of personal interest using their personal photos and music. Many participants found the size and portability of a PDA appealing, one remarking, "It's small enough to carry with me everywhere". Some participants didn't like the colour scheme of the interface and commented that it would be nice to be able to change it.

These results show that, to be usable by older adults, a PDA's interface needs to be flexible and be able to take account of user abilities and preferences. All users, including those with poorer levels of vision or dexterity need to be accommodated. Text and audio input were found to be difficult, and minimal user input using a finger was preferred. Interface components need to be large enough to accommodate this. Audio and visual output need to complement user abilities in terms of volume and size. The interface needs to be intuitive to avoid the need for having to remember how to navigate through a system and perform actions. Users require a simple, friendly interface, with minimal components presenting them only with necessary information and choices.

Requirements Specification

The outcomes of this study were employed in developing a detailed requirements specification. Seven functional requirements were identified to address twelve problems identified in the study.

FR1: Maintain user profiles. To ensure the interface adapts to suit each individual, information needs to be stored on each user.
FR2: Provide a facility to adjust ability settings for vision, hearing and dexterity.
FR3: Provide a facility to adjust the user preference for the interface colour scheme.
FR4: Provide personalised interaction for users.
FR5: Provide continuous support through a visible on-screen help facility.
FR6: Provide simple navigational options through the interface for the user.
FR7: Provide a facility to adjust the user preferences for the output modalities (audio and visual).

The non-functional requirements related to the layout of the interface components and reducing the cognitive load for the user.

NRF1: Reduce cognitive load for user by providing an intuitive interface.
NRF2: Present the features and layout of the system interface in accordance with the International Standards Organisation (ISO) standard, ISO/IEC JTC 001/SC 35/WG 04, user interfaces for mobile device, and the Microsoft guidelines for Pocket PC Development.

Due to the preference for multimedia (i.e., photos and music) mentioned earlier, the interface would facilitate access to an application to assist reminiscence by presenting multimedia combinations in the form of 'memory stories' and participants from the study suggested that it be called MemoryLane.

MEMORYLANE DESIGN AND IMPLEMENTATION

The second and third stages of the USID methodology were the design and implementation of the intelligent interface and application. To address the functional requirements, it was necessary to design and create a database to store user preferences for interface presentation and output, in addition to data on users' physical abilities in terms of vision, hearing and dexterity. To enable MemoryLane to make decisions for each user, it was then necessary to design and implement a rule-based system (RBS) to accommodate individual requirements. The interface can present itself differently to suit each individual user and the multimedia output can be combined to suit the user's abilities and preferences. Figure 1 shows the system architecture for MemoryLane.

There are five architectural components: a Configuration System, which records users' abilities (vision, hearing and dexterity) in the database - this system is used to compile information on each user before using the device and application.; a database which stores user profiles and data on the multimedia items and user preferences; a speech engine to facilitate the use of Text-To-Speech (TTS) in MemoryLane; an SD card to store the actual multimedia items; and an intelligent Rule-Based-Reasoning (RBR) system which governs system functionality, the adaptation of the interface and the composition of memory stories. Seven different output modalities (music, sound effects (FX), songs, narration, text, photos and video) can be used as output for the memory stories, where combinations of suitable output modalities are selected based on the user's abilities and preferences.

The configuration system is stand-alone and designed purely to enable the correct setting of the initial interface for each user's abilities for vision, hearing and dexterity. Two levels of each ability were used (1 = Normal, 2 = Reduced), therefore eight combinations for the three abilities (vision, hearing and dexterity) were possible, as shown in Table 1. Combination 1, for example, is the setting for a user with normal levels of all three abilities.

Figure 1. MemoryLane architecture

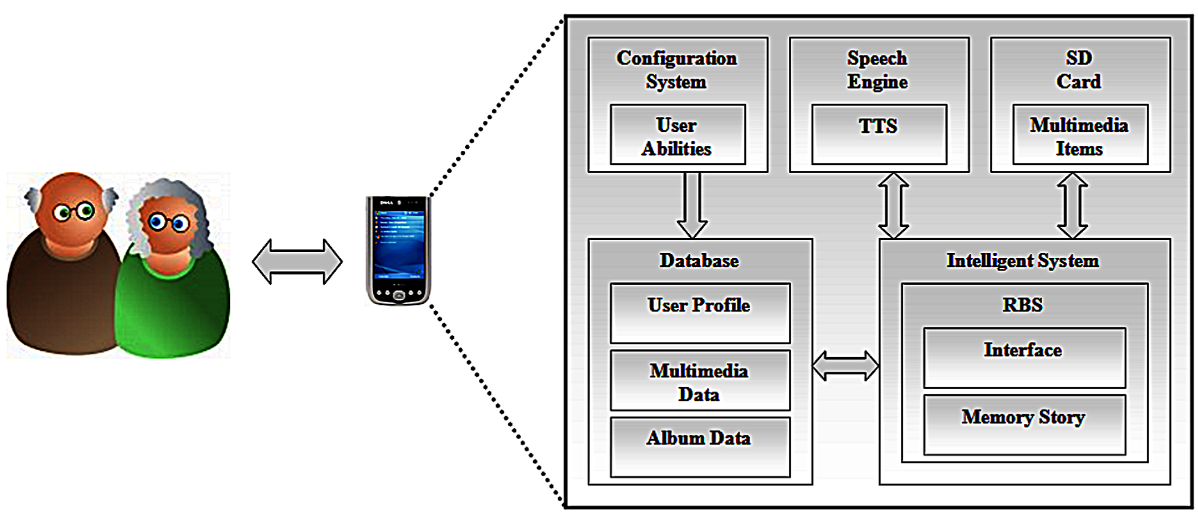
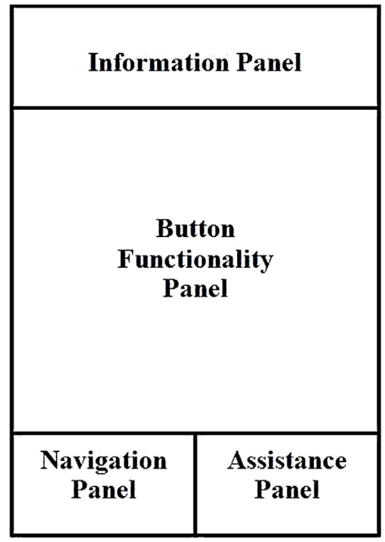


Table 1. Abilities combinations

Combination	Abilities		
	1 = Normal, 2 = Reduced		
	Vision	Hearing	Dexterity
1	1	1	1
2	1	1	2
3	1	2	1
4	1	2	2
5	2	1	1
6	2	1	2
7	2	2	1
8	2	2	2

The intelligent rule-based system (RBS) comprises a complex network of coded rules which use the ability settings and user preferences to derive an interface and output to suit each combination. The vision setting governs the use/non-use of the system TTS voice facility, where on-screen text is read aloud to the user in the event of reduced vision, and also the usage of visual modalities for output, i.e. video, photos and text. The hearing setting determines the volume levels and the usage of audio output modalities, i.e. music, songs, sounds and narration. The dexterity setting governs the size of on-screen buttons. These settings are used to adapt both the multimodal interface and output to the current user's abilities. For example, combination 6 represents a user with reduced levels of vision and dexterity and normal hearing levels. A user with this setting would be presented with normal/default volume levels, enlarged on-screen buttons and bold text of font size 16 to accommodate reduced dexterity. The user with this setting would also be afforded the following combinations of output modalities for their memory stories: limited use of text, photos and video to accommodate the reduced vision, and full use of music, songs and sounds to accommodate normal hearing. Memory story narration would be set to 'on', and the TTS voice functionality to read the on-screen text prompts aloud would also be set to 'on'.

Figure 2. Standard interface template



A facility to adjust these ability settings is available, should the user's abilities change or should they not like the interface and output selected for them. The user can also select their preferred interface colour scheme.

A standard interface template was designed to present choices to the user in a simple layout. This standard template is shown in Figure 2 and is used consistently throughout the application and adapted where appropriate. The Microsoft guidelines for Pocket PC Development were considered in the layout and presentation of this template. There are four main panels: the Information Panel, the Button Functionality Panel, the Navigation Panel and the Assistance Panel.

The Information Panel presents clear and concise text instructions to the user. The instruction informs the users about the purpose of each screen and what options are available. For example on opening the application the user is given the opportunity to either, 'Change your details' (edit profile), or, 'Look at memories' (view memory stories). This information will also be read aloud to the user if vision is reduced. The Button Functionality Panel presents only the necessary functionality for the options referred to in the Information Panel. For example, in the case of the opening screen, two buttons would be provided, one to provide the user with the option to edit their user profile, and the second to provide the option to view memory stories (Figure 3(a)). To ensure simple navigation throughout the application the Navigational Panel provides the user with the means of navigating backwards, forwards or exiting as appropriate. A continuous, visible on-screen help facility is provided by the Assistance Panel which presents a help button that will provide clear context-sensitive help to the user. Each time the help button is pressed, a help message is displayed relating to the screen in use. The help message is displayed on screen for the length of time necessary for it to be read aloud by the system TTS voice facility should the user have reduced vision.

MemoryLane was implemented using Visual Studio. Users log in and their user profile is retrieved from the database, and the interface and output are then adjusted accordingly for that user. An opening screen greets the user by name and moves on to present two options: the opportunity to edit their stored profiles (e.g. change the way the screen is presented) and the opportunity to view 'memory stories', e.g. photos, videos, music relating to a chosen topic. Each interface is intelligently adapted to suit the abilities and preferences of the current user since the RBS accesses the information in the database to make a decision. An example of the implemented 'Opening Screen' for a user with abilities combination 3 from Table 1: reduced vision (2); normal hearing (1); and normal dexterity (1) is shown in Figure 3(a). The standard interface template was used. The Information Panel at the top of the screen displays the text: 'Would you like to...', indicating that the user can make a choice. The Button Functionality Panel presents two (un-outlined) buttons: one to "Look at memories"; and the second to 'Change your details'. An Exit button is provided in the navigational panel and a Help button is provided in the assistance panel. Each time the Help button is pressed, the Help Rule is fired and a help message is displayed. An example of the help message given for the Opening screen is presented in Figure 3(b). This message will also be read aloud to the user as vision is reduced.

Edit User Settings: Change Your Details

If the user chooses to change stored details, two further options are presented: 'Edit Preferences' and 'Edit Abilities'. Under 'Edit Preferences' the

Figure 3. (a) Opening screen (b) help message

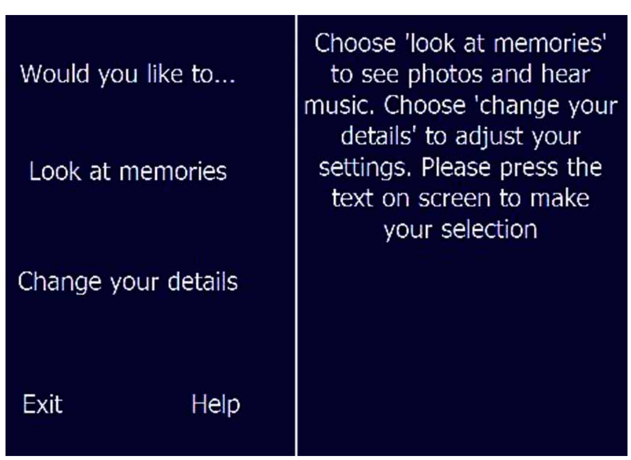
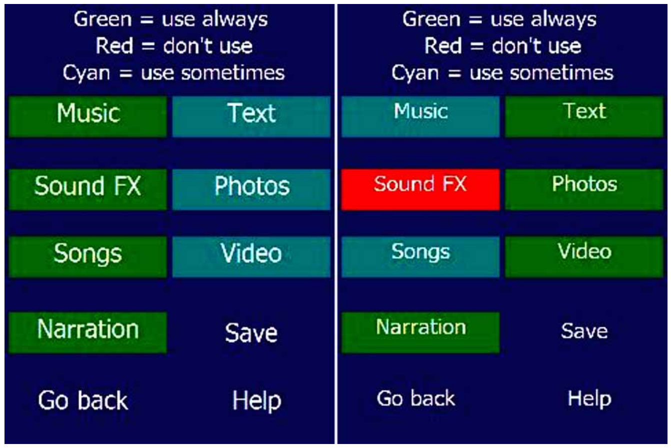


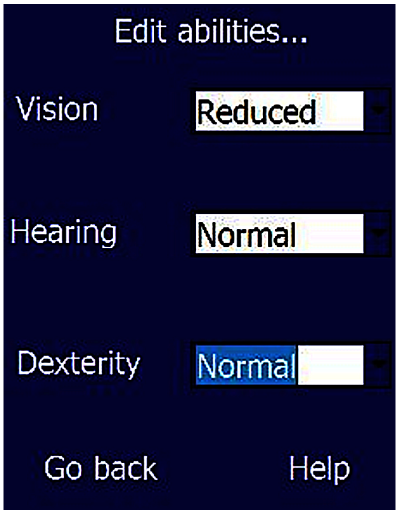
Figure 4. (a) MemoryLane selected output modalities (b) user selected output modalities



user can adjust the combination of the seven output modalities intelligently selected for them by the system based on their abilities and preferences. The system establishes a default setting for each user based on the information gained from the initial configuration. Three choices in terms of output modalities are available and each is colour coded: "use always" (green), "use sometimes" (cyan), "don't use" (red). The user can change the default settings and save the changes. Figure 4(a) shows MemoryLane's selection of output modalities for a user with the abilities combination 3 (normal vision and dexterity and reduced hearing). Based on these ability settings: music, sounds, songs and narration have been set to 'use always' (green), text, photos and video have been set to 'use sometimes' (cyan), and no output modalities are set to 'don't use' (red) since none are unsuitable for a user with this combination of abilities. The user can adjust these default output modality settings, should their needs or preferences change, by pressing the buttons and rotating through the three colours to find the desired setting. Figure 4(b) shows the status of each output modality after the user has changed the settings. Pressing the Save button saves the new output modality settings in the database. These will remain the same unless the user changes them using this facility again, or if the user changes their ability settings (vision, hearing, dexterity), whereby new default output modality settings will be set to suit.

Under the 'Edit Preferences' option users also have the option to gave a 'rating' to individual multimedia items and this rating governs the frequency with which the items are included in memory stories. Rating choices are 1 (never include), 2 (include sometimes) and 3 (include often). The user can also choose to turn the TTS voice facility, which reads on-screen text aloud, on or off under this option. Also, the user is given the opportunity to change the interface colour scheme, for background and text, to one of six different choices of colour scheme. If the user chose the 'Edit Abilities' option when choosing to change details from the opening options, the interface in Figure 5 is shown. The screen is based on the standard interface template, but is slightly adapted to contain combo boxes in the Button Functionality Panel. The settings for a user, again with abilities combination 3, is depicted, i.e. reduced vision (2); normal hearing (1); and normal dexterity (1). To change these settings the user presses the required combo box to display and select an alternative setting. Changes to ability settings will immediately affect the interface, the output modalities and the media items used in memory stories. Each selection is automatically saved in the database.

Figure 5. Edit abilities interface screen



Viewing Multimedia: Look at Memories

On choosing to look at memories from the opening interface, the user can choose to view either a newly created memory story on a topic of their choice, or a previously seen and saved memory story stored in the database in an album for each user. As new memory stories are always dynamically created and are unique, an album facility is provided for users to store their favourite memory stories for subsequent viewing. Users are also given the facility to play, stop and re-play a memory story and also have the ability to save, overwrite and delete memory stories from their album. The construction and delivery of memory stories is performed using a complex set of rules stored in the RBS which makes its decisions based on the user's stored abilities and preferences. In the fourth stage of the USID methodology - the testing

Table 2. Number of participants in age groups

Age Range	60-65	66-70	71-75	76-80	81-85	86-90	Total
Group 1	2	5	3	4	3	3	20
Group 2	4	3	4	6	2	1	20

stage - each section of code was tested as it was developed to ensure that it performed correctly before being integrated with larger sections of code. When it was established that all code sections were working together properly, the final system was rigorously tested as a whole. Each area of MemoryLane functionality was subdivided into 'test cases'. All test cases were individually examined and any errors found were rectified. The final stage – evaluation – is presented in the following section. The results of a detailed evaluation by older adults show significant improvements in the usability of the mobile interface when using the intelligent interface and in the levels of satisfaction experienced.

EVALUATION AND RESULTS

The aim of MemoryLane was to assist older adults using a small mobile computing device. Therefore it was hypothesised that:

The use of intelligent techniques within a mobile computing interface, to enable its adaptation to suit individual preferences and abilities, improves its usability for older adults.

Design of the Experimental Study

Forty new volunteers, twenty males and twenty females, took part in this study (n = 40). Participants were drawn from the University of the Third Age (U3A), the Older People Together in Creativity (OPTIC) Group, Age Concern and community groups. Participant ages ranged from 60 to 90, with a mean age of 74. Participants were randomly assigned to two groups (n = 20) by gender to ensure an equal split in each group (ten male and ten female). Table 2 shows the number of participants within each age range for each group: 35% of the participants were aged seventy and below, and 65% of the sample was aged over seventy.

A user task was developed to perform once on a PDA using MemoryLane (ML), and once on a PDA without intelligent support (PDA). All experiments were conducted in-the-field to ensure an appropriate context setting for social reminiscence and were performed in a one to one format between experimenter and participant. The groups differed in the order in which they carried out the experiment. Participants of Group 1 tested MemoryLane in Phase 1, followed by the PDA in Phase 2. Participants of Group 2 tested the PDA first in Phase 1, followed by MemoryLane in Phase 2, as shown in Table 3. This ordering was applied to counterbalance any possible prejudices or pre-conceptions participants may have regarding their second experiment phase.

Over half (25) of the forty participants had no prior computing experience. Just over one quarter (11) of participants had prior computing experience in excess of two years and the remainder had up to two years experience. No participant had any previous PDA experience and nineteen (47.5%) had no previous experience with mobile phones. By contrast, the same number had over two years experience using mobile phones and the remainder (2) had up to two years experience. Before any experiments were conducted, participants' abilities in vision, hearing and dexterity were recorded using the Configuration System. Overall, 72.5% of participants had normal vision, 55% had normal hearing and 65% had normal dexterity. A summary breakdown of each group's abilities is shown in Table 4. A small number of participants reported quite pronounced debilitating levels of vision, hearing and dexterity.

Table 3. Experiment phase plan

Experiment	Group 1	Group 2
Phase 1	ML	PDA
Phase 2	PDA	ML

Participants were given a demonstration of how to interact with the PDA using each system: the PDA with MemoryLane interface and application loaded, and the PDA with no intelligent support. Participants were allowed free time to spend working with the device before beginning the task, when they were then invited to reminisce about an 'anniversary party' using the multimedia stored on the device. The same task was repeated using both systems. Participants were allowed to take as little or as much time as they liked to complete the task. Experiment phases (MemoryLane and PDA) lasted for approximately one hour each and were conducted consecutively with a short break between. Participants' interactions were measured using both quantitative and qualitative methods. Four 'performance metrics' were recorded for each participant using each system during the course of their interaction, and all sessions were observed. The metrics measured were:

- **Help:** The number of help requests (both verbal to the researcher and via the system) made during interaction.
- **Clicks:** The number of screen clicks (taps with a finger or the stylus) made during interaction.

Table 4. Summary of participants' abilities by group

Ability	Group 1		Group 2	
	Normal %	Reduced %	Normal %	Reduced %
Vision	65	35	80	20
Hearing	50	50	60	40
Dexterity	55	45	70	30

- **Media:** The number of media items viewed (or heard) during interaction.
- **Errors:** The number of errors made during interaction.

Analyses

The data was analysed using SPSS version 17. Since the task was repeated twice in this study, Repeated Measures Analyses of Variance (RM-ANOVAs) were used to compare performances between the two systems (MemoryLane and PDA). Investigations were then conducted to find out if participants' abilities (vision, hearing, dexterity), ages, gender or prior experience contributed to the findings. These results were combined with the results from post-experiment questionnaires, observations and informal interviews to establish the effectiveness and usability of MemoeyLane.

The independent variables were Group (1 and 2, i.e. the order in which experiments with MemoryLane and PDA were undertaken) and System (MemoryLane and PDA). The dependent variables were the scores for the performance metrics on each system. Sphericity was assumed throughout as there were only two levels of repeated-measures conditions; thus they are linear. The SPSS alpha level was set to 0.05, therefore any value less than this will result in statistically significant results.

Analysis of Performance Metric Help

This metric was used to measure how intuitive each system's interface and the interaction with them were. The assumption was that if higher levels of help were requested then the system interface and interaction with it were less intuitive. This RM-ANOVA compared participants' scores for the number of help requests for MemoryLane against the number of help requests for PDA. The RM-ANOVA reported a substantial main effect of System ($F\ (1, 38) = 163.574$, $p < 0.0005$, partial eta squared = 0.811) with a much lower number of help requests for MemoryLane. The large F ratio and the p value of less than 0.05 denote that this difference has not occurred by chance, and, using Cohen's (1988) criterion, partial eta squared confirms this to be a large effect. All participants found the PDA much more difficult to use than MemoryLane and required considerably more assistance when completing the task on this system. The independent variable, Group, did not have a significant main effect ($F\ (1, 38) = 0.014$, N.S.). The interaction effect between System and Group also failed to achieve significance (System x Group, $F(1, 38) = 1.127$, N.S.). The difference was not due, therefore, to the order in which participants completed the task (MemoryLane-PDA or PDA-MemoryLane). All participants, irrespective of group placing, requested significantly more help when completing the participant task on the PDA.

Further RM-ANOVAs were conducted to ascertain if the significant difference in the number of help requests between the two systems could be attributed to a particular user attribute (gender, age, vision, hearing, dexterity, computing experience and mobile phone experience). Since Group had no main effect on the results, it was not a factor in these analyses. The independent variable in each analysis was each user attribute in turn. Gender, vision, hearing, computing experience and mobile phone experience were all found to have no significant main or interaction effect on the number of help requests. There were no main effects found for age or dexterity, however both had a moderate interaction effect with the number of help requests ($F(1, 34) = 2.619$, $p < 0.05$, partial eta squared = 0.278), and ($F(1, 38) = 4.165$, $p < 0.05$, partial eta squared = 0.099) respectively. The interaction effect for age and help requests is shown in Figure 6.

The average scores for each system are displayed in boxes. As expected, the results show that in the main, when using MemoryLane, participants' average number of help requests increased with age, except for the oldest participants (86 - 90) who were closer to the overall average number of help requests of 2.93. Participants from the other

Figure 6. Interaction effect between help requests and system for age

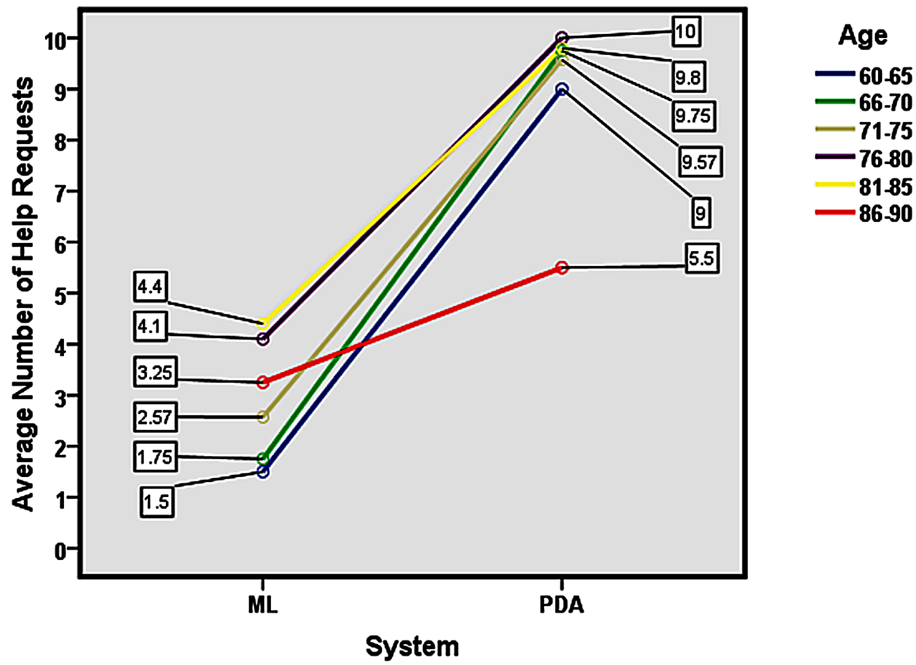
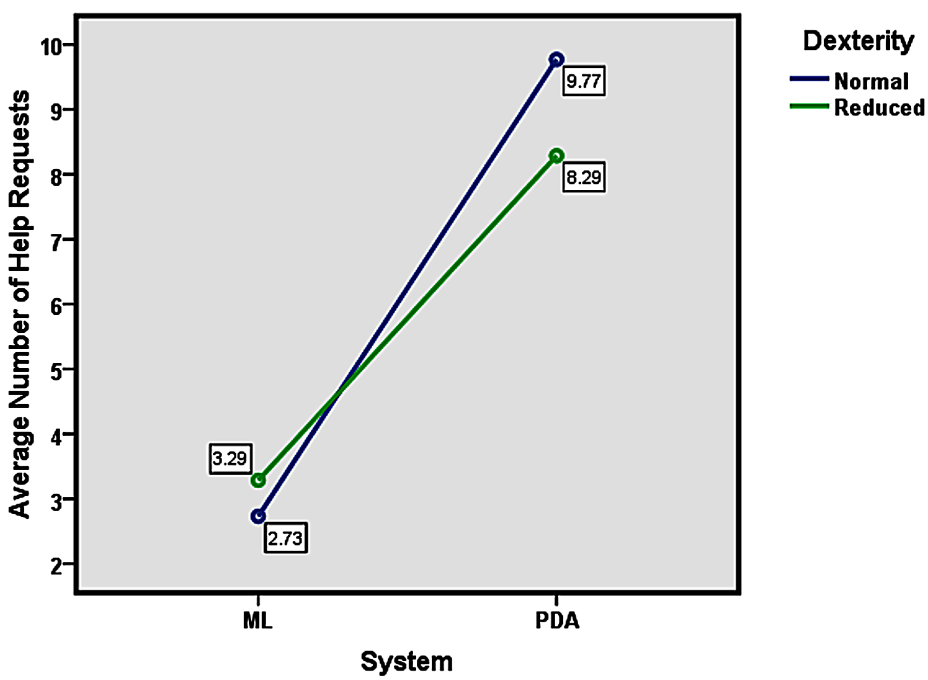


Figure 7. Interaction between help requests and system for normal and reduced dexterity



age brackets requested up to eight times more help when using the PDA. From observation, the amount of assistance requested varied with the degree to which participants engaged with the device. Some of the participants commented: "I'm too old for all this now", and, "It's for younger folk", and produced low counts on help requests as a result. The interaction effect for dexterity and help requests is shown in Figure 7.

Results are similar for both systems and both levels of dexterity, with less help requests for MemoryLane. On average, it can be seen that participants with normal dexterity levels requested help two - three times when using MemoryLane and nine - ten times when using the PDA, and participants with reduced dexterity levels requested help three times when using MemoryLane and eight times when using PDA. It is interesting to note that, on average, participants with reduced levels of dexterity requested slightly less help than their counterparts on the PDA system with no support provided. This could be attributed, from observation and informal feedback, to a reluctance to fully engage with the PDA system, with many saying that they, "couldn't touch the screen in the right places", and that this made them feel very, "self-conscious", and therefore unwilling to ask for further help. All participants requested substantially more help when using the PDA and indicated that this was the more difficult system to use.

Analysis of Performance Metric Clicks

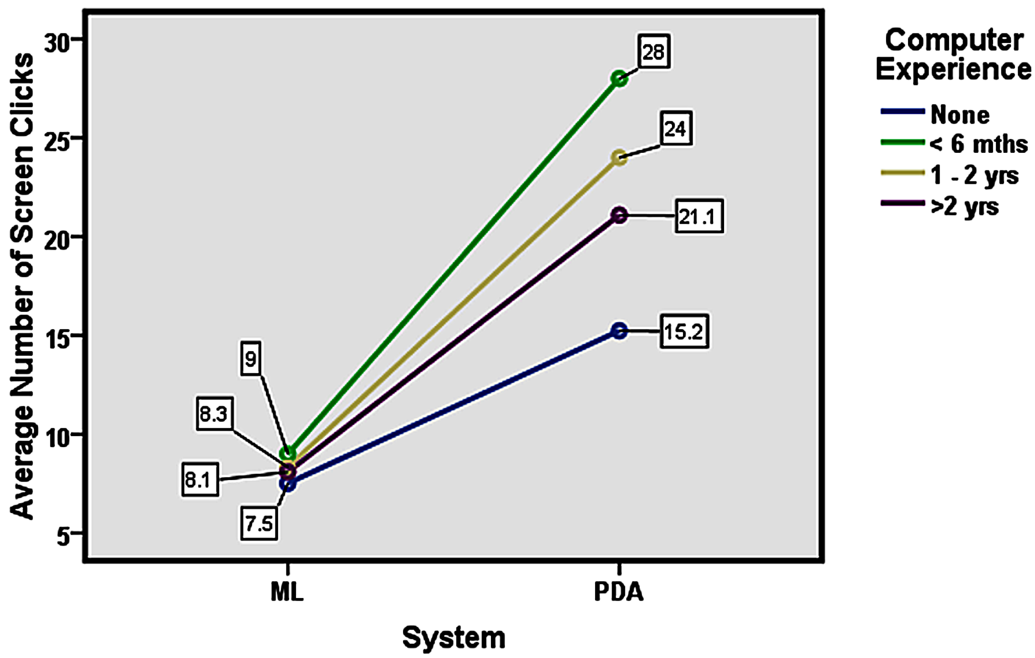
This RM-ANOVA compared participants' scores for the number of screen clicks made during the task interaction. As with the Help performance metric, it was assumed that fewer clicks meant MemoryLane was more usable and required less effort on the part of the participant. It should be noted however, that MemoryLane, by its nature does not require as much interaction as the PDA system since multimedia is automatically generated for the user. The results showed a huge increase in the number of screen clicks made on the PDA when compared to MemoryLane. The RM-ANOVA reported a substantial main effect of System, ($F(1, 38) = 86.274$, $p < 0.0005$, partial eta squared = 0.694). Overall, the mean number of screen clicks for MemoryLane was significantly lower than the mean number of screen clicks for the PDA. The significant difference in screen clicks between the two systems was not differentially affected by group (order of experiment), gender, age, mobile phone experience and all abilities (vision, hearing and dexterity) whether reduced or normal. None were found to have either a significant main or interaction effect. Participants' previous computing experience was found to have a significant main effect on the number of screen clicks made ($F(1, 36) = 3.292$, $p < 0.05$. partial eta squared = 0.215) and also a significant interaction effect ($F(1, 36) = 3.303$, $p < 0.05$, partial eta squared = 0.216). This interaction effect is graphically presented in Figure 8.

Participants with no computing experience at all had the lowest average numbers of screen clicks on both systems. From observation, this can be explained by the fact that many of the inexperienced participants were more hesitant when interacting with the systems and were "afraid of getting it wrong" and consequently were less adventurous, making fewer screen clicks. All participants made substantially more screen clicks when using the PDA. From observation, some participants found the amount of clicking quite demanding, making comments such as: "There's an awful lot to do, isn't there?", and, "I can't remember where to do all this clicking".

Analysis of Performance Metric Media

This RM-ANOVA compared participants' scores for the number of media items viewed (or heard) during the participant task interaction for MemoryLane and the PDA. It was expected that there would be a substantial difference in the number of media items viewed on the two systems, with the assumption that the more media items viewed (or heard), the more rewarding the interaction would be. Results showed that participants were able

Figure 8. Interaction between screen clicks and system for computer experience



to see and hear considerably more media items when using MemoryLane than when using the PDA. On average, participants viewed almost ten times (32.55) more media items on MemoryLane than on the PDA (3.35). There was a substantial main effect of System, ($F(1, 38) = 798.797$, $p < 0.0005$, partial eta squared = 0.955). Once again, the order of the task (Group) did not affect results, and there was also no significant interaction effect between System and Group. The results of further RM-ANOVAs show that the significant difference in media items viewed between the two systems was not differentially affected by previous computing experience, mobile phone experience, gender or abilities (vision, hearing or dexterity). None were found to have either a significant main or interaction effect.

The RM-ANOVA which analysed media items viewed and age did however report a large main effect: ($F(1, 34) = 2.656$, $p < 0.05$, partial eta squared = 0.281) with a higher number of media items viewed for ML. There was, however, no interaction effect between system and age. Results show that participants in the 66 - 70 age bracket viewed the most media items on both systems, with a mean of 36.63 items on the ML system and a mean of 5 items on the PDA. Participants aged 81 - 85, with a mean of 24.6, viewed the least media items on MemoryLane, and the second least on the PDA with a mean of 2.40. The oldest participants, in the 86 – 90 age bracket viewed an average of 30.75 items on MemoryLane and the least amount of items on the PDA with a mean of 2.25. From observation it was clear that these participants were satisfied with this result. The oldest participants, aged 86 - 90, viewed the least media items on the PDA with a mean of 2.25. Observation showed that this was due to difficulties in navigating the interface and finding the media items. These results show that there was a significant difference in the amount of media items viewed by participants as they completed the participant task on the two systems. All participants saw and heard substantially more media items when using MemoryLane, and indicated that they found this the more rewarding system to use.

Analysis of Performance Metric Errors

The fourth performance metric to be analysed was the number of errors made by each participant using each system. As with the previous analyses, it was expected that there would be a substantial difference in the number of errors made on the two systems, with the assumption that participants would make fewer errors on the more usable system. Results showed that participants made considerably more errors when using the PDA than when using MemoryLane; on average, participants made eight times more errors with the RM-ANOVA reporting a substantial main effect of System, ($F(1, 38) = 28.333$, $p < 0.0005$, partial eta squared = 0.872). The results again show that there was no significant main or interaction effect for Group (experiment order).

Further RM-ANOVAs were conducted to ascertain if the significant difference in the number of errors made between the two systems could be attributed to a particular profile aspect. Two profile aspects showed an effect: age and dexterity, the same two user attributes which affected the performance metric help. Although the main effect for age was non-significant, an interaction effect was found ($F(1, 34) = 2.768$, $p < 0.05$, partial eta squared = 0.289). This interaction effect is shown in Figure 9, again with averages displayed in boxes. The results show that when using MemoryLane, participants' average number of errors increased with age with one exception to this in that participants aged 81 - 85 made fewer errors than their younger counterparts in the 76 - 80 age group. Strangely, this result was almost reversed using the PDA. On the PDA the average number of errors made did not increase with age. From observation, the amount of errors made using the PDA varied with the degree to which participants engaged with the device. One older participant commented: "I've had enough of that one" (the PDA).

Figure 9. Interaction between errors and system for age

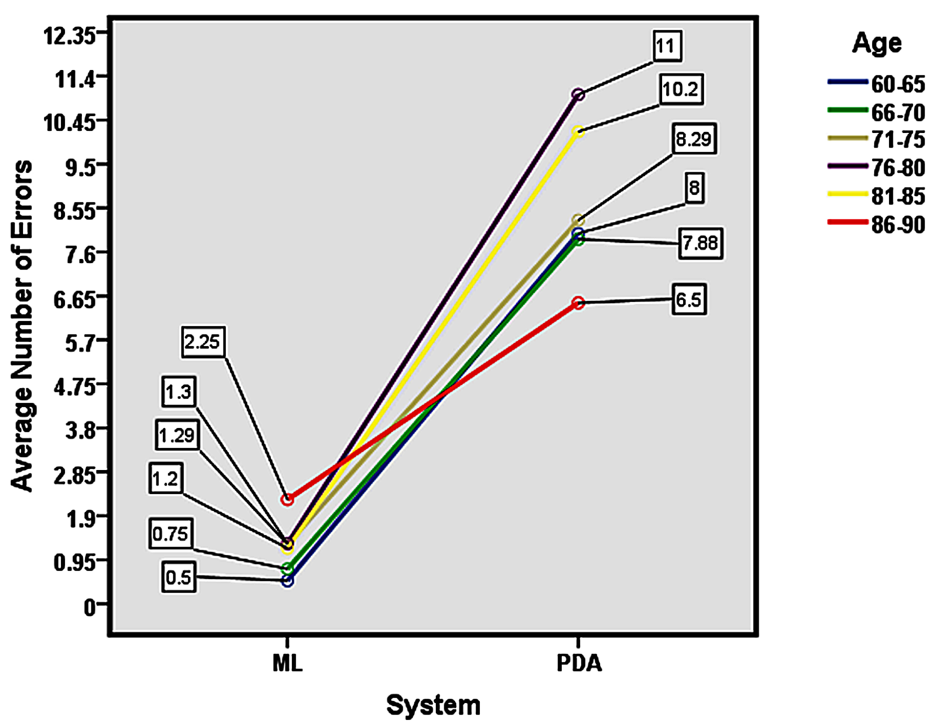
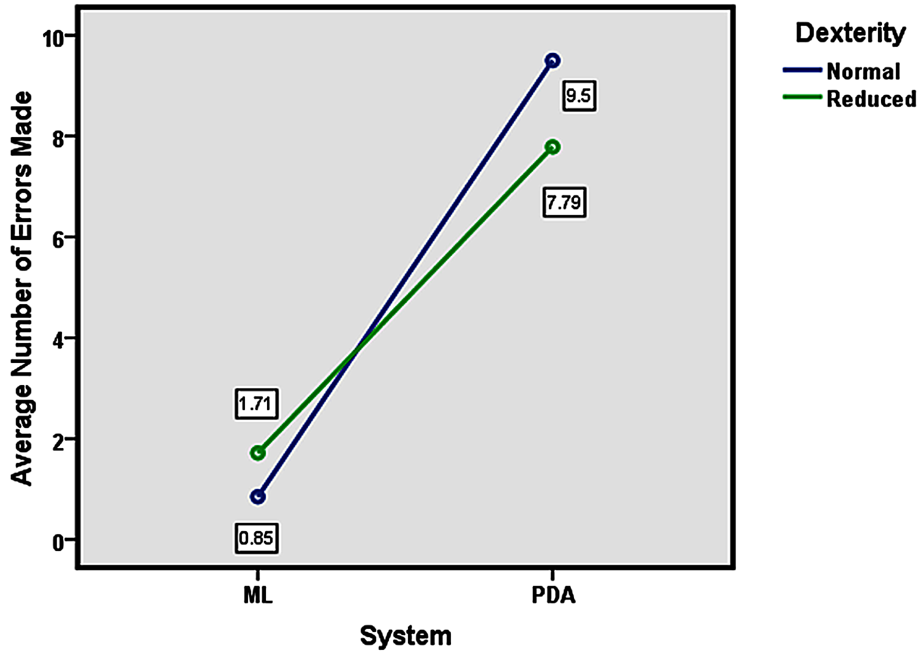


Figure 10. Interaction between errors and system for normal and reduced dexterity



There was also a large interaction effect between dexterity and the number of errors made ($F(1, 38) = 7.876$, $p < 0.05$. partial eta squared $= 0.172$). This interaction effect is presented in Figure 10. Interestingly, on average, it can be seen that participants with normal dexterity levels made fewer errors on the ML system and more on the PDA, whereas the participants with reduced dexterity levels made more errors on the ML system and less on the PDA. From observation, this was probably due to reluctance to engage fully with the PDA due to having poor levels of dexterity, as many participants commented that that they were, "Afraid of getting it wrong'', and for those who completed MemoryLane first, that the PDA was, "just not as easy to use as MemoryLane", and "I made so many mistakes, everything is far too small". This result for Dexterity, however, given participants' comments and obvious observed frustrations, should be viewed with caution since many abandoned the PDA task quickly due to the problems encountered. The results certainly show just how difficult participants with dexterity problems find it to use small, mobile computing devices. These results show that there was a significant difference in the amount of errors made by participants as they completed the participant task on the two systems. All participants made substantially more errors when using the PDA, indicating that this was the more difficult system to use.

Post-Experiment Questionnaires

Participants were asked to complete post-experiment questionnaires after each experiment phase. The questionnaires were designed to assess the usability of both systems and contained quantitative ratings and qualitative open-ended questions. While qualitative comments are often deemed participantive and as such provide no empirical measures for system comparison, they still provide valuable insight into participants' accurate reflections regarding their interaction. The questionnaires addressed the following three general areas of usability:

- **Effectiveness:** Task completion by participants.
- **Satisfaction:** Quality of participant experience.
- **Learnability:** How intuitive is the design?

Questionnaires adopted the 5 point Likert scale technique where participants rated their agreement with a statement on a scale from (1) strongly agree to (5) strongly disagree with the statements shown in Table 5. Results show that the participants consistently rated MemoryLane better than the PDA, irrespective of their group (experiment order), gender, age, vision, hearing, dexterity, computing experience or mobile phone experience.

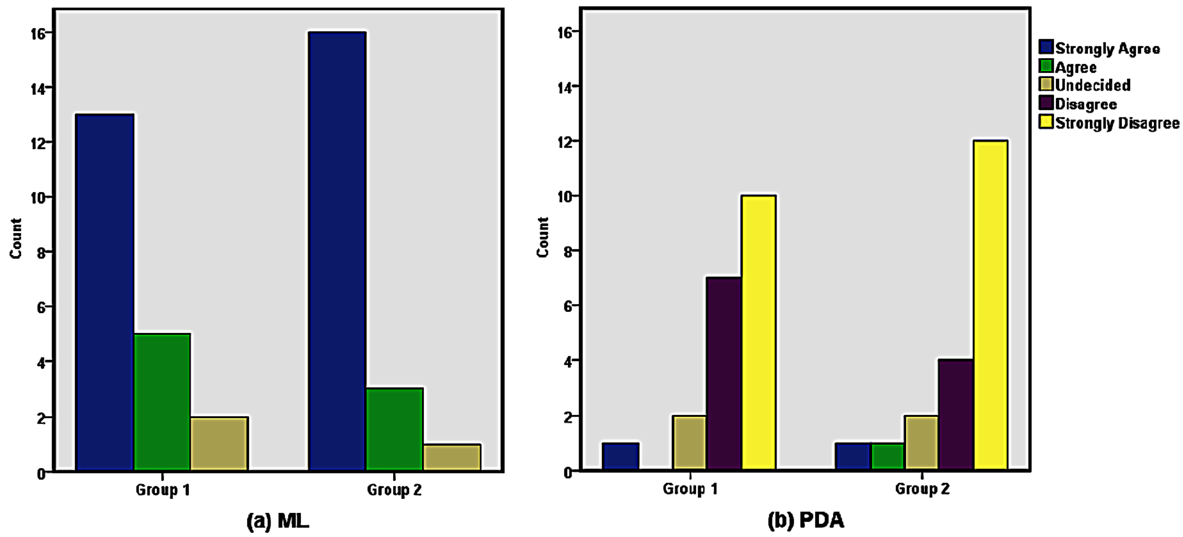
For statement 1, "I found it simple to complete the task using this device", no one disagreed and only 5 (7.5%) were undecided when using MemoryLane. The rest agreed (72.5% (29) agreed strongly). Conversely, the results for the PDA show that 55% (22) strongly disagreed with the statement, with an additional 27.5% (11) disagreeing. 10% (4) remained undecided, 5% (2) strongly agreed and 2.5% (1) agreed. The agreement with this statement by three participants using the PDA is surprising, as it is clearly unsupported by observation results. It is likely that this is due to 'over-reporting' by participants in the study, where a minority of participants simply answered all questions posed favourably in an attempt to either 'get it right' or 'please the researcher. Indeed, a small group of participants frequently tended to answer all questions as strongly agree for both systems. This small group of participants continued the trend of over-reporting for the PDA throughout the questionnaires yet this was not reflected in the performance metrics scores recorded for the PDA, or in the levels of frustration observed. The vast majority of participants agreed that it was simpler to complete the task on MemoryLane. These findings are shown in Figure 11 for each group using each system.

Table 5. Post-experiment questionnaire statements

Number	Questionnaire Statement
1	I found it simple to complete the task using this device.
2	I was able to complete the task quickly using this device.
3	I found the task enjoyable.
4	The interface was easy to understand.
5	I could hear everything easily.
6	I found the text easy to read.
7	It was easy to touch the screen in the right places.
8	I could see everything clearly.
9	I liked the interface.
10	It was easy to learn how to use the interface.
11	I always knew what to do next.
12	I did not feel frustrated or anxious.
13	I did not need to get help very often.

Although the time taken to complete the participant task was not an issue for the study, participants were asked how they rated their speed with the system in achieving the desired goal in statement 2 – "I was able to complete the task quickly using this device". Again, experiment order was not an issue, with most participants (85%) agreeing (65% strongly) that they were able to complete the task more quickly when using MemoryLane. Six participants (15%) remained undecided and none disagreed. The results for the PDA show the reverse result in that twenty-three participants (57.5%) strongly disagreed with the statement, with an additional twelve participants (30%) disagreeing, and 5% (two participants) were undecided. As before, there is evidence of participant over-reporting on the PDA, with two participants (5%) strongly agreeing with this statement, and a further 2.5% (one participant) agreeing. However, it was obvious from observation that participants had to apply more time and effort with disappointing results while attempting the participant task on the PDA.

Figure 11. I found it simple to complete the task using this device

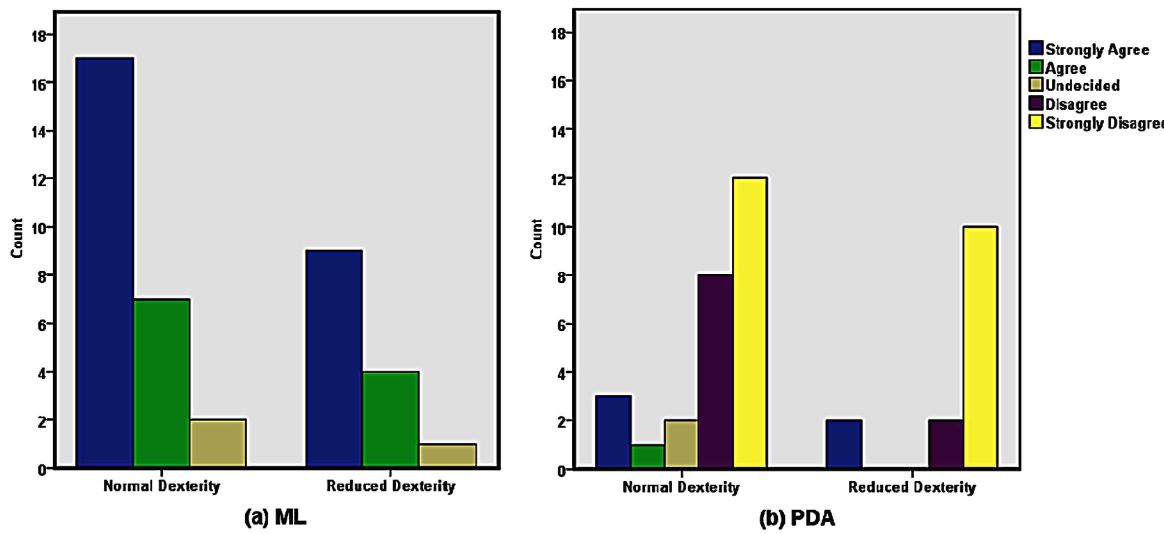


The results from the remaining statements follow this trend repeatedly reporting MemoryLane as the favoured system. For statement 3 – "I found the task enjoyable" - 95% (38) participants agreed when using ML. Two participants (5%) were undecided and nobody disagreed. This was backed up by participant comments such as, "I enjoyed it immensely, it excited me and made me happy", and, "It would cheer me up if I was down". In contrast for the PDA, fifteen participants (37.5%) disagreed with this statement, a further sixteen participants (40%) strongly disagreed and five participants (12.5%) were undecided. Many participants commented that the whole experience was simply "not enjoyable!". In light of this, it is interesting to see that three participants (7.5%) actually strongly agreed with this statement with an additional one participant (2.5%) agreeing. Again, from observation, this is probably due to participant over-reporting, since it cannot be backed up by user feedback.

For statement 4 – "The interface was easy to understand" - 95% (38) agreed using MemoryLane with the other 5% (2) remaining undecided. On the other hand only 7.5% (3) agreed with this statement when using the PDA. A further 7.5% (3) were undecided and the rest (85% - 34) either disagreed or strongly disagreed. These results support the results from the requirements analysis study that older adults find a PDA interface difficult to use. MemoryLane's interface was found to be more usable and intuitive than that of the PDA. These results were backed up by participant comments such as, "I felt in charge", "It was always obvious what to do next", and, "It was easy for a first time user".

Similarly for statement 5 - "I could hear everything easily." - 95% (38) agreed that they could hear everything easily using MemoryLane with 5% (2) undecided. As previously discussed, 45% (18) reported reduced hearing. Of this percentage it can be seen that 94.5% either strongly agreed or agreed that they could hear clearly with 5.5% remaining undecided, thus indicating that MemoryLane met the needs of those participants with reduced hearing. Only 25% (10) agreed with the statement using the PDA system, and a large number were undecided (35% - 14). 40% (16) found it difficult to hear everything on the PDA and ten of these strongly disagreed with this statement. All of those with reduced hearing (45%) are included in the disagreement results for the PDA. Of the

Figure 12. It was easy to touch the screen in the right places



55% of participants with normal hearing, on the other hand, 36% still reported problems with hearing and also disagreed with this statement. From observation, this was largely due to the fact that they did not recall how to find and/or use the volume control on the PDA.

Statement 6 – "I found the text easy to read." – allowed participants to rate the degree to which they found the text easy to read on both systems. This result was unaffected by normal or reduced levels of vision. Thirty-five participants (87.5%) found the text easy to read on MemoryLane, and five participants (12.5%) remained undecided. Of the eleven participants (27.5%) who reported reduced vision, 81.5% either strongly agreed or agreed with this statement, thus indicating that MemoryLane met the needs of those participants with reduced vision. Using the PDA there were disagreements with this statement with twenty-six participants (65%) not finding the text easy to read. Seven participants (17.5%) said they could, and a further seven (17.5%) were undecided. Nine of the eleven participants with reduced vision disagreed or strongly disagreed that they found the text easy to read, however two participants strongly agreed with the statement. Once again, most of the participants reported that it was much more difficult to see things clearly on the PDA.

The results from participants' responses to statement 7 – "It was easy to touch the screen in the right places" - showed once again that MemoryLane outperformed the PDA for both levels of dexterity (Figure 12). Thirty-seven participants (92.5%) were able to interact with MemoryLane's interface touch-screen with no problems. The remaining three (7.5%) were undecided. Thirty-five percent of participants had reported reduced dexterity (14); therefore this is an excellent result. Results for the PDA were much poorer. Only six participants (15%) felt that the interaction with the touch-screen was easy, two (5%) were undecided, while thirty-two (80%) disagreed.

The degree to which participants could see everything clearly on both systems (statement 8 – "I could see everything clearly") was unaffected by normal or reduced levels of vision. Thirty-eight participants (95%) agreed, with 30 participants agreeing strongly. One participant (2.5%) was undecided, and one (2.5%) disagreed. Of the eleven participants who reported reduced vision, ten participants (90%) either strongly agreed or agreed that they could see everything clearly, thus indicating once again that MemoryLane met the needs of those participants with reduced vision. The participant who disagreed with the statement had particularly bad cataracts in both eyes and was at a severe visual disadvantage from the outset. Using the PDA twenty-six participants (65%) disagreed with the statement, with eight participants (20%) strongly disagreeing. Seven participants (17.5%) agreed with statement, five of these strongly agreeing that they could see everything clearly, and seven participants (17.5%) were undecided. Nine of the 11 participants with reduced vision disagreed or strongly disagreed that they could see everything clearly, and unexpectedly, two participants with reduced vision strongly agreed that they could. Overall, the vast majority of participants reported that it was much more difficult to see things clearly on the PDA system.

The degree to which participants liked the interface of both systems (statement 9 – "I liked the interface") was unaffected by experiment order (Group). No one disliked MemoryLane's interface, thirty-six participants (90%) reported that they liked the interface, and four participants (10%) remained undecided. Comments such as: "I liked the simplicity of the device, it was simple to see all and easy to read", and, "I liked the clarity of the screen" strongly supported this rating. Thirty-two participants (80%) disliked the PDA interface, with eighteen of these participants strongly disagreeing with the statement. Comments such as: "I can't make it (the PDA interface) out", and, "I don't really understand it", support these findings. Only three participants (7.5%) liked the PDA interface, from observation this result could be due to over-reporting as none of these participants found interaction easy and none stated why they liked the PDA interface. Five participants (12.5%) remained undecided; these results show that participants clearly preferred MemoryLane's interface.

The degree to which participants found it easy to learn how to use the interface (statement 10 – "It was easy to learn how to use the interface") on both systems was also unaffected by experiment (Group) order. Thirty-six participants (90%) agreed that it was easy to learn how to use MemoryLane's interface, while four participants (10%) remaining undecided. When asked why, one lady said that she was nervous during the task and felt she "could've done better. The other three said that they felt they could "learn how to use the interface" given more time. Thirty-four (85%) participants disagreed with the statement when using the PDA system and 28 of these strongly disagreed. Three participants (7.5%) agreed that it was easy to learn how to use the PDA interface, although from observation this was not apparent. Three participants (7.5%) were undecided. These results show that MemoryLane's interface proved intuitive to use, and is backed up by comments such as, "Clear instructions to follow", and, "It's easy to learn how to use it (MemoryLane)".

The degree to which participants always knew what to do next (statement 11 – "I always knew what to do next") when using both systems was also unaffected by experiment order (Group). When using MemoryLane twenty-three participants (57.5%) strongly agreed with this statement, with a further eleven participants (27.5%) agreeing, and four participants (10%) remaining undecided. Two female participants (5%) reported that they felt that they were unsure of "what to do next", although from observation, this was clearly not the case as both seemed very confident and neither required help. Both had limited computing background, and may have had limited confidence as a result, but it was not evident as they progressed. Three participants (7.5%) reported that they always knew what to do next using the PDA. These participants had previous computer experience. The one participant who remained undecided said that he knew what to do, "some of the time", but, on occasion, found himself "at a loss" during the task. Ninety percent (36) reported disagreement (57.5% strongly). These results show that participants knew what to do next on MemoryLane more easily and are supported by participant comments such as, “I never felt lost”, and, “It seemed obvious what to do next”.

Results for statement 12 – “I did not feel frustrated or anxious” – were similar for both Groups with experiment order again not affecting the results. For MemoryLane, 65% (26) strongly agreed, 25% (10) agreed and 10% (4) were undecided. When using the PDA, the percentage of frustration and anxiety reported was much lower than expected given the observations noted. This could be due to many of the participants’ reluctance to fully engage with the PDA system, and also due to the amount of help requested and provided. The average number of help requests with MemoryLane was 2.93, and this was over three times greater with the PDA with an average number of help requests of 9.55. Twenty-two participants (55%) reported feelings of frustration or anxiety when using the PDA. Seven participants (17.5%) said they did not feel frustrated or anxious and eleven participants (27.5%) were undecided. It is possible that the amount of assistance given led participants to not feeling as frustrated or anxious as they might have been without the support. Frequent comments such as: “I got confused easily, I didn’t like it” and, “I kept needing to concentrate very hard”, when combined with the amount of help supplied, point towards this conclusion.

Statement 13 asked participants to rate the statement that they did not need to get help very often, and once again, experiment order (Group) did not affect the results with a similar pattern emerging. Thirty-three participants (82.5%) either strongly agreed or agreed with this statement when using MemoryLane. Six participants (15%) were undecided but these participants felt that they “didn’t know” if the help they had requested was “a lot” or “a little”. One lady commented that she felt that by saying she requested help frequently it would make her “look silly”. Another asked “was it (the amount of help she requested) the same as everybody else?”. One participant (2.5%) disagreed with this statement when using MemoryLane. On the other hand, when using the PDA, twenty-eight participants (70%) reported needing substantial assistance, with sixteen of these in the strongly agreeing category. Five participants (12.5%) were undecided if they needed frequent help, and seven participants (17.5%) felt that they didn’t need help very often. One of the more frequent comments during PDA interaction was, “I had to ask for lots of help”. All help requests made with the PDA were verbal. No one managed to find help via the PDA help facility. The main areas which caused participants to seek help using the PDA were:

- Not knowing what to do next.
- Not knowing where to click on the screen to proceed.
- Unsure of what interface components meant.
- Navigational problems, getting lost in the system (frequently how to ‘go back’).
- Not knowing how to recover from mistakes.
- Not knowing where to get help from the system.

The majority of the help requests made with MemoryLane, on the other hand, were via the system help buttons. Participants were interested to, “See what it (MemoryLane’s help facility) tells me to do here”. Verbal help requests were usually for confirmation of actions; for example: “Can I do this?”, “Am I allowed to do this?”, and, “what happens if I do this?”.

DISCUSSION

This work clearly demonstrates that the provision of an interface capable of adapting itself to meet the abilities and preferences of individual users significantly improves older people’s interaction, performance and general experience when using small mobile computing devices. The involvement of older people in the development process is essential in addressing their needs. The initial usability study conducted with target users highlighted just how difficult older people, often with very little prior computing experience, found a PDA interface use, and enabled the key usability issues to be clearly identified and a solution designed and developed. An evaluation, again with target users, has shown that such devices can be effectively used by older people when the necessary assistance is provided based on each user's individual needs.

From the statistical analysis using the four performance metrics, it was found that both users' age and dexterity levels had significant effects on the amount of assistance requested and the number of errors made with older users making higher numbers of errors and requiring higher levels of assistance. Further work, however, needs to be conducted with larger numbers of participants within the older age range to establish what can be done to further address the problems faced by these users. In addition to this, this study used only two levels of ability – reduced and normal – and future work with greater granularity in the levels of abilities may help to tailor the assistance to individuals more effectively. In particular, there is scope for further work to investigate the impact of reduced dexterity through the use of voice input to reduce the need for screen interaction.

Although this work focuses on older users as the target user group, the principles of intelligent, adaptable interfaces and dynamic multimodal input and output could be utilised in other areas where the diversity and needs of users are of paramount importance. Further work could be extended to include younger people with physical disabilities, for example. Also, further work could be conducted to investigate the incorporation of additional intelligent techniques such as Artificial Neural Networks (ANNs) which would allow the system to 'learn' from each user and make decisions based on that learned profile while adapting appropriately as changes are then detected. User settings could then be dynamically changed by the intelligent system itself, rather than requiring the user to take action to change them as is the case here. The issue of user control, however, needs to be considered carefully, since undisclosed changes may cause further confusion. Generic multimedia items were used in this study that were not specific to any one participant. Individual applications would, naturally, store the owner's personal multimedia items and further work is necessary to establish the effect of using multimedia specific to the participants themselves. Also, if a device were to be shared by several people, then further development of the current login procedure would be necessary. A login screen, for example, could display photographs of all users as a method of login, with a password facility perhaps combined with text or speech input and output.

User feedback tended to concentrate on two areas: the multimodal input and output provided by the system, and the functionality of the interface. Feedback suggests that there is scope for further work to increase the `intelligence' of interaction. For example, participants particularly liked the personalisation of the interface and the reminiscence application in the use of their names, and suggestions included requests for further work in this area. One suggestion was for, "the system could be more chatty", in that it might behave more like a friend and allow for conversation. The facility to include conversational interaction could be provided by using natural language processing (NLP) in the same manner as online chat-bots. Issues in terms of speech input and output would need further investigation with target users to establish the effectiveness of this suggestion and its technical limitations within a mobile device. Another suggestion relating to speech was for the use of the user's own voice for narration instead of the TTS voice provided by the system. This, although feasible, would significantly extend the time required for setting up the application for use, requiring recording of the stories for each individual user. Further suggestions related to the provision of additional colour schemes and interface features such as an on-screen slider option for volume control. Other possibilities include a magnifying glass or landscape or portrait options. The possibility of providing further interface functionality from which users could decide what they would like to see displayed within the limits of the screen requires investigation. The inclusion of such facilities, however, needs to be considered in the light of available screen space and further experiments would need to be conducted to consider their effects on usability.

This work has established a framework for future research and development in this area. The results of this study could be formally incorporated into a set of guidelines for the development of mobile device interfaces. The results provide a strong foundation upon which to build more complex hybrid intelligent support within a structured environment. By focusing on the target users throughout, this research has established the most prominent usability problems encountered by older people when interacting with a mobile interface, and has shown how intelligent support can significantly alleviate them. Throughout this research, further potential improvements were identified, in many cases, the most useful pointers for further developments in interface support came from the older people themselves, providing an excellent opportunity to address specific issues appropriately. This work has demonstrated how it is possible to reduce the need for older adult users to search through complex menu hierarchies; it has simplified selections, made the interface easier to understand and reduced the need for excessive interaction by incorporating intelligent support. Further work has been suggested which could enhance the functionality offered by such an intelligently adaptive interface, although attention must be paid to the possibility of increasing complexity in the attempt to incorporate increased functionality. Essentially, it is important that target users are involved throughout any further design and development as they are key to achieving a balance between complexity and usability.

CONCLUSION

This research has shown how mobile device usability by older people can be significantly improved by including older people in the development process itself and by incorporating adaptability through the use of intelligent techniques. Further studies need to be conducted to ascertain if increasing interface functionality, perhaps using additional on-screen objects, can be achieved without adding to complexity which could lead to increased anxiety and frustration levels. Further work could also be conducted to investigate how the research conducted here could be used to support or create other mobile applications, thereby extending the techniques used in this research into other mobile device applications targeted specifically at older people, and other user groups where adaptability is key.

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REFERENCES

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Mahwah, NJ: Lawrence Erlbaum Associates.

Darroch, I., Goodman, J., Brewster, S. A., & Gray, P. D. G. (2005). The effect of age and font size on reading text on handheld computers. In *Proc. of the 2005 IFIP TC13 International Conference on Human-Computer Interaction* (pp. 253-266). Heidelberg, Germany: Springer-Verlag. doi:10.1007/11555261_23

Digital Unite. (2014). *Digital unite - Helping older people unleash their digital talents*. Retrieved from http://digitalunite.com/

Eisma, R., Dickinson, A., Goodman, J., Mival, O., Syme, A., & Tiwari, L. (2003). Mutual inspiration in the development of new technology for older people. In Proc. of Include 2003 (Vol. 7, pp. 252-259). Helen Hamlyn Research Centre, Royal College of Art.

Fisk, A. D., Rogers, W. A., Charness, N., Czaja, S. J., & Sharit, J. (2004). *Designing for older adults: Principles and creative human factors approaches*. Boca Raton, FL: CRC Press. doi:10.1201/9781420023862

Garritty, C., & El Emam, K. (2006). Who's using PDAs? Estimates of PDA use by health care providers - A systematic review of surveys. *Journal of Medical Internet Research*, *8*(2), e7. doi:10.2196/jmir.8.2.e7 PMID:16867970

Gillingham, W., Holt, A., & Gillies, J. (2002). Hand-held computers in healthcare - What software programs are available. *The New Zealand Medical Journal*, *115*(1162), U185. PMID:12386664

Goodman, J., Brewster, S., & Gray, P. (2004). Older people, mobile devices and navigation. In J. Goodman & S. Brewster (Eds.), *Proc. of the Workshop on HCI and the Older Population*. BCS HCI.

Hawthorn, D. (2003). How universal is good design for older users? In *Proc. of the 2003 conference on Universal usability (CUU '03)* (pp. 38-45). New York, NY: ACM. doi:10.1145/957205.957213

Liang, H., Xue, Y., & Byrd, T. A. (2003). PDA usage in healthcare professionals - testing an extended technology acceptance model. *International Journal of Mobile Communications*, *1*(4), 372–389. doi:10.1504/IJMC.2003.003992

Money, A. G., Lines, L., Fernando, S., & Elliman, A. D. (2008). Older adults' experiences of interacting with online forms. In *Proc. of Workshop on HCI and the Older Population at the 22nd BCS HCI Group Annual Conference on People and Computers XXII: Culture, Creativity, Interaction* (*Vol. 2*). Liverpool, UK: John Moores University.

Newell, A. F., & Gregor, P. (2000). User sensitive inclusive design, in search of a new paradigm. In ScholtzJ.ThomasJ. (Eds.), *Proc. on the Conference on Universal Usability*. Arlington, VA: ACM. doi:10.1145/355460.355470

Older People's Day. (2011, September 29). *Statistical bulletin*. Office for National Statistics. Retrieved from http://www.statistics.gov.uk/

Race Online 2012. (2012). Retrieved from http://raceonline2012.org/

Selwyn, N. (2004). The information aged - A qualitative study of older adults' use of information and communications technology. *Journal of Aging Studies*, *18*(4), 369–384. doi:10.1016/j.jaging.2004.06.008

Sterns, A. A. (2005). Curriculum design and program to train older adults to use personal digital assistants. *The Gerontologist*, *45*(6), 828–834. doi:10.1093/geront/45.6.828 PMID:16326666

Zajicek, M. (2001). Interface design for older adults. In *Proc. of the 2001 EC/NSF Workshop on Universal Accessibility of Ubiquitous Computing: Providing for the Elderly* (pp. 60-65). New York, NY: ACM. doi:10.1145/564526.564543

KEY TERMS AND DEFINITIONS

Human-Computer Interaction (HCI): HCI involves the study, design, planning and uses of interaction between people and computers.

Intelligent Systems: Software and hardware computer systems and machines which perform tasks we normally only think of people doing such as speech, hearing and vision are considered intelligent systems.

MemoryLane: A software system on a mobile device for older people that provides multimodal content on life-cached data such as photos, videos, music and poems based on their user preferences and physical abilities.

Multimodal: Multimodal Human Computer Interaction refers to interaction with the physical and virtual environment through natural modes of communication, i.e. modes involving hearing, vision, touch, smell and taste.

Personal Digital Assistant (PDA): A mobile device that functions as a personal information manager. Most PDA's employ touchscreen technology.

User Physical Abilities: Users interacting with computers can have various degrees of physical abilities in respect of different modalities (e.g. hearing, vision, touch) which can limit their capacity for interaction.

User Preferences: During interaction with computers users can choose preferences for how they wish to interact. For example, users may prefer more or less audio, vision or haptic (touch) interaction modalities.